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Software Users Manual for the Polar Ice Prediction System Version 2.0

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The Polar Ice Prediction System Version 2.0 is an ice-ocean coupled system that provides daily forecasts of ice drift, ice thickness, and ice concentration for most ice-covered areas in the Northern Hemisphere. The model is driven by daily atmospheric forcing from the Navy Operational Global Atmospheric Prediction System. The model is initialized from its own previous 24-h forecast with an additional weak constraint back to Levitus climatology placed on the ocean temperature and salinity.

This Software Users Manual (SUM) provides instructions for the operation and use of the PIPS2.0 system. The SUM also includes information concerning the input/output of the system and the necessary commands to execute the forecast system.

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SOFTWARE USERS MANUAL FOR THE POLAR ICE PREDICTION SYSTEM VERSION 2.0

1.0 SCOPE

1.1 Identification

This Software Users Manual (SUM) provides instructions for the operation and use of the Computer Software Configuration Item (CSCI) identified as the Polar Ice Prediction System Version 2.0 (PIPS2.0). This SUM has been prepared in accordance with guidelines set forth by the Fleet Numerical Meteorology and Oceanography Center (FNMOC). These guidelines are based on the Data Item Description (DID) DI-MCCR-80019A (dtd 29 Feb 1988) of DOD-STD-2167A.

1.2 System Overview

PIPS2.0 was developed as an ice-ocean coupled system to provide daily forecasts of ice-drift velocity, ice thickness, and ice concentration for most ice-covered regions in the Northern Hemisphere. (This includes the area from the North Pole, south to approximately 30° N.)

PIPS2.0 is a self-contained model with the required oceanic forcing being computed within the model itself. Two independent models were merged to form PIPS2.0: the Hibler Viscous-Plastic Sea Ice Model, which provides the ice prediction output, and the Cox Ocean Model, which provides the ocean forcing required as input for the Hibler Ice Model. To accomplish the merger, the models were first independently adapted to the required prediction basin and then joined by a common driver routine. Information between the coupled models is exchanged via common blocks.

In this configuration, the ocean model provides daily predictions of mixed-layer temperatures, variable freezing temperatures, oceanic heat fluxes, and ocean currents to the ice model, while the ice model supplies the ocean model with ice concentration, ice growth rate, ice thickness, ice thickness growth rate, ice surface temperature, ice-drift velocity, and heat above the freezing temperature.

The basis of the ice model is the Hibler dynamic/thermodynamic ice model (Hibler 1979; 1980) that was modified for operation in the polar regions (Preller and Posey 1989) and updated for spherical coordinates (Cheng and Preller 1992). The ocean model is the Cox primitive equation, numerical model (Cox 1984) that predicts horizontal and vertical velocities, temperature, and salinity for a three-dimensional ocean basin. Daily Navy Operational Global Atmospheric Prediction System (NOGAPS) data supplies the atmospheric data for forcing.

The PIPS2.0 ice-ocean coupled system is presently in research and development use at the Naval Research Laboratory (NRL) Detachment, Stennis Space Center, MS, and is being implemented

at FNMOC. PIPS2.0 is designed to run on a UNIX host platform. For greater applicability, host system specifics are kept to a minimum in this document.

1.3 Document Overview

This SUM provides detailed instructions to operate PIPS2.0 for daily forecasts of the ice-covered regions specified in Sec. 1.2. Step-by-step procedures for executing the software, including initialization, operation, termination, and restart; and guidelines for preparing input and interpreting output are given in Sec. 2.0. Abbreviations and acronyms used in this document are listed in Sec. 4.0. The user who requires a more detailed discussion of the algorithms and equations is referred to the PIPS2.0 Software Design Document (Preller et al. 1996).

2.0 EXECUTION PROCEDURES

2.1 Initialization

PIPS2.0 is initialized with the previous day's 24-h forecast, including the ice model and ocean model restart files and the ocean currents from the last two timesteps, and from the monthly river discharge rate and historical Levitus ocean temperatures and salinities. It is forced with NOGAPS atmospheric data and the previous day's predicted ice conditions. All initialization data are provided to PIPS2.0 via these input files:

PIPS2.0 previous day's ocean model currents and ice growth rates
PIPS2.0 previous day's ice model restart fields
PIPS2.0 previous day's ocean model restart fields
Levitus monthly averaged temperatures
Levitus monthly averaged salinities
NOGAPS data
River discharge rates
Grid position data
Land/Sea Mask

These initialization input files are described in the subparagraphs that follow, starting with the external initialization files (Sec. 2.1.1) and following with the PIPS2.0-generated 24-h forecast results (Sec. 2.1.2).

2.1.1 External Data Files

2.1.1.1 Levitus Climatology

The Levitus temperatures and salinities are read from a file connected to logical units 10 and 11, respectively. Levitus temperatures and salinities are provided as input files for the month of the calculation. The temperature filename is for018_tu_*MM*.dat (see sample display that follows) and, similarly, the salinity filename is for018_su_*MM*.dat where, in both cases, the *MM* is replaced by the month of the calculation.

FILE FORMAT for018_tu_*MM*.dat

Logical Unit Number: 10
File Access Method: unformatted sequential access
Data Stored in File:

RECORD	DATA	DESCRIPTION
1	TMIX(361,361,15)	Levitus temperatures for ocean basin grid cells

FILE FORMAT for018_su_*MM*.dat

Logical Unit Number: 11
File Access Method: unformatted sequential access
Data Stored in File:

RECORD	DATA	DESCRIPTION
1	SMIX(361,361,15)	Levitus salinities for ocean basin grid cells

2.1.1.2 NOGAPS Atmospheric Data

NOGAPS forcing data are read from a file connected to logical unit 12. The filename is p*YYMMDD*.dat, where *YY* is the year, *MM* is the month, and *DD* is the day of the calculation. NOGAPS daily atmospheric data provide the forcing for the ice model.

FILE FORMAT p*YYMMDD*.dat

Logical Unit Number: 12
File Access Method: unformatted sequential access
Data Stored in File:

RECORD	DATA	DESCRIPTION
1	TA(361,361)	air temperature
2	PSA(361,361)	surface pressure
3	ESA(361,361)	surface vapor pressure
4	FSH1(361,361)	incoming solar radiation
5	PSB(361,361)	total heat flux
6	ESB(361,361)	sensible heat flux

2.1.1.3 River Discharge

The monthly river discharge rates and temperatures are read from a file connected to logical unit 19. The filename is river_*MMM*.dat, where *MMM* is the three-character month.

FILE FORMAT river_*MMM*.dat

Logical Unit Number: 19
File Access Method: unformatted sequential access
Data Stored in File:
for IRV = 1, 88 IRIVER(IRV), JRIVER(IRV), KRIVER(IRV), RIVER(IRV)

DATA	DESCRIPTION
IRIVER(IRV)	x component of river discharge
JRIVER(IRV)	y component of river discharge
KRIVER(IRV)	z component of river discharge
RIVER(IRV)	river discharge temperature

2.1.1.4 Earth-Oriented Latitudes and Longitudes

Latitude positions for each gridpoint are read from a file connected to logical unit 14. The latitudes, in Earth-oriented spherical coordinates, are defined in file newlatu.dat.

FILE FORMAT newlatu.dat

Logical Unit Number: 14
File Access Method: unformatted sequential access
Data Stored in File:

RECORD	DATA	DESCRIPTION
1	FCORSP(361,361)	Earth-oriented latitudes for each gridpoint

2.1.1.5 Land/Sea Masks

Land/sea boundary tables are read from a file connected to logical unit 15. The land/sea masks for thermodynamic fields, velocity fields, and outflow grid cells are defined in file mask_u.dat.

FILE FORMAT mask_u.dat

Logical Unit Number: 15
File Access Method: unformatted sequential access
Data Stored in File:

RECORD	DATA	DESCRIPTION
1	UVM(359,359)	velocity field land/sea boundary
	HEFFM(360,360)	thermodynamic field land/sea boundary
	OUT(360,360)	outflow grid land/sea boundary

2.1.2 PIPS2.0-Generated Data Files

2.1.2.1 Ocean Model Currents and Ice Growth Data

PIPS2.0 outputs ocean currents for the last two timesteps, and ice growth rate data, which are read back in from logical unit 13. The filename is for010_*mmdd*.dat, where *mmdd* represents the month and day.

FILE FORMAT for010_*mmdd*.dat

Logical Unit Number: 13
File Access Method: unformatted sequential access
Data Stored in File:

RECORD	DATA	DESCRIPTION
2 records for 2 to 359	J1, ITT	present timestep meridianal gridpoint index, timestep counter
	UTEMP(360),VTEMP(360), TMP(360,2)	present timestep x component, y component of ocean current, temperature, salinity
2 records for 2 to 359	J1, ITT	previous timestep meridianal gridpoint index, timestep counter
	UTEMP(360),VTEMP(360), TMP(360,2)	previous timestep x component, y component of ocean current, temperature, salinity
	GICE(360,360) SHICE(360,360) FW1(360,360)	ice thickness growth rate of open water, total ice thickness, heat above freezing

2.1.2.2 Ice Model Restart File

PIPS2.0 outputs the ice model restart file named *yymmdd*.res, where *yymmdd* represents the year, month, and day, which is read back in from logical unit number 16. This file contains ice-drift velocity, ice thickness, ice concentration, and mixed-layer temperature.

FILE FORMAT *yymmdd.res*

Logical Unit Number: 16
File Access Method: unformatted sequential access
Data Stored in File:

RECORD	DATA	DESCRIPTION
1	UICE(359,359,3)	x component of ice-drift velocity
2	VICE(359,359,3)	y component ice-drift velocity
3	UICEC(359,359)	intermediate x component of ice-drift velocity
4	VICEC(359,359)	intermediate y component of ice-drift velocity
5	HEFF(360,360,3)	mean ice thickness per grid cell
6	AREA1(360,360,3)	ice concentration per grid cell
7	TICE(360,360)	mixed-layer temperature in the case of open water; ice temperature in the case of ice cover

2.1.2.3 Ocean Model Restart File

PIPS2.0 outputs the ocean model restart file containing tracer and horizontal velocity data for the three most recently processed timesteps, which are read back in from logical unit 18. The filename is fort_*yymmdd*.21, where *yymmdd* represents year, month, and day. This file is direct access, written, and read internally within PIPS2.0 using Ocean Direct Access Manager (ODAM) off-the-shelf software.

FILE FORMAT fort_*yymmdd*.21

Logical Unit Number: 18
File Access Method: direct access
Data Stored in File:
The following data for for rows J, J+1, and J–1, the previous, current, and next timesteps:

DESCRIPTION	DATA
T	tracer data for N+1 timestep, row J
U, V	U and V components of horizontal velocity for N+1 timestep, row J
FKMU	number of vertical levels of ocean at U,V points
WSY	tracer data for N–1 timestep, row J+1

2.2 User Inputs

User inputs are read through the standard input device, either via keystroke or via a run shell script. They are entered directly following the program execution command as free-format input in a prescribed order. The following required inputs, in order, are:

ITSTEP	Number of timesteps for run
PLTSTP	Interval in timesteps at which to plot results
PRTSTP	Interval in timesteps at which to print results
IRSTRT	Restart indicator: 1 for restart, 0 for climatology restart
IDTG	Eight-character date-time-group of the model run, YYMMDDHH.

All user inputs are integer values. A suggested value for all but the date-time-group is listed in the example below.

USER INPUTS		
VARIABLE	SUGGESTED VALUE	
ITSTEP	8	Each timestep is 3 h; 8 timesteps provide a 24-h forecast.
PLTSTP	8	With PLTSTP the same as ITSTEP, data for the last timestep is plotted.
PRTSTP	8	With PRTSTP the same as ITSTEP, data for the last timestep is printed.
IRSTRT	1	Restart is the normal mode of operation.

2.3 Operation

Once all of the initialization files are located, running PIPS2.0 is straightforward. Four simple steps must be followed.

a) Assign the logical units used for PIPS2.0 execution. Begin by clearing any logical units that were previously assigned using the **assign -R** command.

```
assign -R
```

Then assign the unit numbers to be used by PIPS2.0 as ieee data format using the following command:

```
assign -F f77 -N ieee u:<unit #>
```

Repeat the command for unit numbers 10 through 15 and 30 and 31.

b) Assign the input data files to specific logical unit numbers:

File	Unit #
for018_tu_*MM*.dat	10
for018_su_*MM*.dat	11
p*YYMMDD*u.dat	12
for010_*mmdd*.dat	13
newlatu.dat	14
mask_u.dat	15
yymmdd.res	16
fort_*mm*.21	18
river_*MMM*.dat	19

Italics in the file indicate the specific year, month, or day. Lower-case italics are for the previous day's date; upper-case italics are for the current run's date. This may be done in UNIX using the **ln** command linking a file to the default file for the specific logical unit number.

```
ln <filename> fort.<unit#>
```

c) Run the model. Enter the model execution name (pips2_c.out), followed by the input data values.

```
pips2_c.out
  <itstep> <pltstp> <prtstp> <idtg>
```

d) Output data are written to specific logical units. Following execution, rename these files from their default file to the following filenames:

Unit #	File
30	for010_*MMDD*.dat
31	*YYMMDD*.dat
33	*YYMMDD*.res
34	fort_*YYMMDD*.21

This renaming may be done in UNIX using the **mv** command, moving a file out of its default logical unit filename to its new filename.

```
ln <filename> fort.<unit#>
```

It is convenient to use a shell script to perform the above functions necessary for running PIPS2.0. The following is a skeleton shell script used to make a single model run.

```
assign -R
assign -F f77 -N ieee u:10
assign -F f77 -N ieee u:11
assign -F f77 -N ieee u:12
assign -F f77 -N ieee u:13
assign -F f77 -N ieee u:14
assign -F f77 -N ieee u:15
#
assign -F f77 -N ieee u:30
assign -F f77 -N ieee u:31
#
ln    for018_tu_MM.dat     fort.10
ln    for018_su_MM.dat     fort.11
ln    pYYMMDDu.dat         fort.12
ln    for010_mm_u2.dat     fort.13
ln    newlatu.dat          fort.14
ln    mask_u.dat           fort.15
ln    yymmdd_u.res         fort.16
ln    fort_mm.21           fort.18
ln    river_MMM.dat        fort.19
#
pips2_c.out << 'EOD'
                                        ! itstep, pltstp, prtstp, irstrt, idtg
'EOD'
#
mv    fort.30    for010_MMDD_final.dat
mv    fort.31    YYMMDD_final.dat
mv    fort.33    YYMMDD_final.res
mv    fort.34    fort_YYMMDD_final.21
```

It is assumed that this shell script is located in the same directory as the executable and input and output files. Path names have to be included with filenames if different directories are used.

Shading is used to highlight where run-specific entries must be made. Following the file-naming conventions described in Sec. 2.1, the shaded upper-case characters represent the year, month, and day of the model run to be inserted. Shaded lower-case characters represent the previous run's date. User input values are to be inserted in place of the shaded blanks, .

2.4 Termination

The program automatically terminates when the timestepping has reached the user input maximum time. The following message is displayed upon normal termination:

```
STOP
```

2.5 Restart

PIPS2.0 is only run in restart mode; it is never started from scratch. A current PIPS2.0 run is dependent on either initialization from the previous PIPS2.0 24-h forecast or initialization from climatology.

2.6 Outputs

PIPS2.0 outputs data to both screen and file. Screen data provides a quick look at the PIPS2.0 run. Displayed are ice thickness, outflow, and ice growth rate values, as well as intermediate timestep information. In the Screen Output subsection that follows, actual output values would be in place of the italicized x's. File output includes a file formatted specifically for post-PIPS2.0 graphics plotting (a currents file that may be used for plotting, but is also used for initialization of the next model run), and two restart files—one from the ocean model portion of PIPS2.0 and the other from the ice model portion. Both are used solely as restart initialization data for the next day's model run.

2.6.1 Screen Output

Upon successful convergence with the ice model relaxation scheme and solving the momentum equation of ice motion, a message is printed to standard output stating the number of iterations that were performed and the maximum error determined for u and v velocity fields.

```
NO. OF ITERATIONS AREA: xxxxx
MAX. ERROR FOR U AND V: xxxxxx.xxxxx
```

The maximum number of iterations allowed in the ice model relaxation scheme is 2000. If the program attempts to perform more than 2000 iterations, the convergence fails and a message is printed to standard output.

```
NO. CONVERGENCE AFTER xxxxxxxx ITERATIONS
```

For each step within the iteration loop, the squared velocity, squared velocity difference between times t and t+1, and the maximum change are calculated and printed to standard output.

```
SQUARE VELOCITY, SQ. VELOCITY DIFFERENCE, MAX CHANGE
xxxxxxx.xxxxxxxxxxxx xxxxxxx.xxxxxxxxxxxx xxxxxxx.xxxxxxxxxxxx
```

The timestep and the date-time-group (IDTG) are printed to standard output for each timestep. The date-time-group is in the form YYMMDDHH, where YY is the two-digit year, MM is the two-digit month, DD is the two-digit day of the month, and HH is the two-digit hour of the day.

```
TIMESTEP - xxxxx IDTG - xxxxxxxx
```

For certain timesteps, one line of timestep information is written to standard output. The information includes the timestep, portion of the year, the day and time of the year in Julian days, the energy, temperature change, salinity change, and the number of relaxation scans.

```
TS = xxxxx   YEAR = x.xx   DAY = xxx.x   ENERGY = x.xxxExxx
                    DTEMP =  x.xxxExxx   DSALT = x.xxxExxx   SCANS = x.xxxExxx
```

For every printing interval in timesteps (user input value PRTSTP), several ice values are printed to standard output.

```
OUTPUT FOR DTG - xxxxxxxx   STEP - xxxxxxxxxx
TOTAL ICE THICKNESS - xxxxxxx.xxxxxxxxxxxx
 NET ICE THICKNESS - xxxxxxx.xxxxxxxxxxxx

OUTFLOW FOR THIS TIMESTEP xxxxx.xxxx
 NET OUTFLOW xxxxx.xxxx

ICE GROWTH FOR THIS TIMESTEP xxxxx.xxxx
NET ICE GROWTH xxxxx.xxxx
OPEN WATER GROWTH xxxxx.xxxx
NET OPEN WATER GROWTH xxxxx.xxxx
OPEN WATER GROWTH xxxxx.xxxx
NET OPEN WATER GROWTH xxxxx.xxxx
```

When the model run is complete, a message is printed to standard output.

```
STOP
```

2.6.2 File Output

2.6.2.1 Graphics Data

The data used to create graphics output is written to a file connected to logical unit number 31. The filename is *YYMMDD*.dat, where *YY* is the year, *MM* is the month, and *DD* is the day of the model run.

FILE FORMAT *YYMMDD*.dat

Logical Unit Number: 31
File Access Method: unformatted sequential access
Data Stored in File:

RECORD	DATA	DESCRIPTION
1	GAIRX(361,361)	x component of the wind, where 361, 361 are the dimensions of the wind field
2	GAIRY(361,361)	y component of the wind
3	HEFF(360,360)	mean ice thickness per grid cell, where 360,360 are the dimensions of the thermodynamic field
4	UICE(359,359)	x component of the ice drift
5	VICE(359,359)	y component of the ice drift
6	AREA1(360,360)	ice mass per grid area

2.6.2.2 Currents and Ice Growth Data

PIPS2.0 outputs currents, for the last two timesteps, and ice growth rate data to logical unit 30. The filename is for010_*MMDD*.dat, where *MMDD* represents the month and day.

FILE FORMAT for010_*mmdd*.dat

Logical Unit Number: 30
File Access Method: unformatted sequential access
Data Stored in File:

RECORD	DATA	DESCRIPTION
2 records for 2 to 359	J1, ITT	present timestep meridianal gridpoint index, timestep counter
	UTEMP(360),VTEMP(360), TMP(360,2)	present timestep x component, y component of ocean current, temperature, salinity
2 records for 2 to 359	J1, ITT	previous timestep meridianal gridpoint index, timestep counter
	UTEMP(360),VTEMP(360), TMP(360,2)	previous timestep x component, y component of ocean current, temperature, salinity
	GICE(360,360) SHICE(360,360) FW1(360,360)	ice thickness growth rate of open water, total ice thickness, heat above freezing

2.6.2.3 Ice Restart Data

PIPS2.0 outputs the ice model restart file to logical unit 33. The filename is *YYMMDD*.res, where *YYMMDD* represents the year, month, and day. This file contains ice-drift velocity, ice thickness, ice concentration, and mixed-layer temperature.

FILE FORMAT *YYMMDD*.res

Logical Unit Number: 33
File Access Method: unformatted sequential access
Data Stored in File:

RECORD	DATA	DESCRIPTION
1	UICE(359,359,3)	x component of ice-drift velocity at three time levels
2	VICE(359,359,3)	y component ice-drift velocity at three time levels
3	UICEC(359,359)	intermediate x component of ice-drift velocity
4	VICEC(359,359)	intermediate y component of ice-drift velocity
5	HEFF(360,360,3)	mean ice thickness per grid cell at three time levels
6	AREA1(360,360,3)	ice concentration per grid cell at three time levels
7	TICE(360,360)	mixed-layer temperature in the case of open water; ice temperature in the case of ice cover

2.6.2.4 Ocean Model Restart File

PIPS2.0 outputs the ocean model restart file containing tracer and horizontal velocity data for the three most recently processed timesteps to logical unit 34. The filename is fort_*YYMMDD*.21, where *YYMMDD* represents year, month, and day. This file is direct access, written, and read internally within PIPS2.0 using ODAM off-the-shelf software.

FILE FORMAT fort_*YYMMDD*.21

Logical Unit Number: 34
File Access Method: direct access
Data Stored in File:
The following data for for rows J, J+1, and J–1, the previous, current, and next timesteps:

DESCRIPTION	DATA
T	tracer data for N+1 timestep, row J
U, V	U and V components of horizontal velocity for N+1 timestep, row J
FKMU	number of vertical levels of ocean at U,V points
WSY	tracer data for N–1 timestep, row J+1

3.0 ERROR MESSAGES

There are no trapped errors in PIPS2.0.

4.0 NOTES

4.1 Abbreviations and Acronyms

CSCI	Computer Software Configuration Item
DID	Data Item Description
FNMOC	Fleet Numerical Meteorology and Oceanography Center
NOAA	National Oceanic and Atmospheric Administration
NOGAPS	Navy Operational Global Atmospheric Prediction System

NRL	Naval Research Laboratory
ODAM	Ocean Direct Access Manager
PIPS2.0	Polar Ice Prediction System Version 2.0
R&D	Research and Development
SDD	Software Design Document
SUM	Software Users Manual

5.0 SUMMARY AND CONCLUSIONS

PIPS2.0 is an ice-ocean coupled system that provides daily forecasts of ice-drift velocity, ice thickness, and ice concentration for most ice-covered regions in the Northern Hemisphere. This SUM provides instructions for the operation and use of the PIPS2.0 system. The SUM includes information concerning the input files needed for the execution of the model. The output files, also described in the SUM, contain the 24-h forecast of ice-drift velocity, ice thickness, and ice concentration.

6.0 ACKNOWLEDGMENTS

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